Using Cellular Static IP for Base to Rover Long Distance RTK with Multiple Vector Analysis

Introduction

Real Time Kinematic Global Positioning System (GPS) or now more formally known as Global Navigation Satellite Systems (GNSS) have become an essential tool for most professional surveyors today. However, unlike Static GPS Network Surveys, most Land Surveyors have sacrificed the ability to analyze and adjust this data using Least Squares for the cost benefits and ease of use of single rover Virtual Reference Stations (VRS) or Realtime Network (RTN) services that provide a subscription based corrections via the internet. Although early adopters, we at Thoth Surveying have never been huge fans of the subscription based services because of the observed vertical accuracies and the lack of a reproducible vector trail.

Make no mistake base and rover systems also offer their own limitations, distance capabilities being the top of our list. Our solution to this problem was to replace conventional radio based corrections with a similar internet based telemetry that allow us to broadcast corrections from the base and receive them to any number of rovers at an extremely reasonable cost. This solution is certainly not new; however, it does seem to have been stymied by most manufacturers for the subscription based solution. (Conspiracy Theory!)

Pros of Subscription based services

The most irritating thing when using a base and rover RTK combination is baseline distance and the equipment required. **Spread Spectrum** is a great solution that does not require an FCC[1] License or additional equipment; unfortunately, it only goes about 2500 feet under perfect conditions (Topography and no blocking structures). **UHF/VHF** Systems can provide distances from 1 to 5 miles, but the longer distance requires more power (battery drain) for internal radios providing 1 watt or external equipment and FCC Licensing for higher wattage systems that can also be restrictive by region and various DOD and Federal Installations. Integrated cellular radios provide a seamless solution using mobile networks to stream network corrections over long distances and relatively small bandwidth requirements allowing connectivity in most regions, however your mileage may vary. However, these are almost only a rover based solution.

There have been a number of whitepapers detailing the benefits of VRS and RTN methods using the Network Transport or RTCM[2] showing that differing methods using multiple base-stations corrections provide reliable accuracy and reduce the ppm[3] degradation by approximately half. The obvious benefit is that you can deploy a single rover connected to the internet to obtain 1 to 3-centimeter level accuracies over an extremely large coverage area depending on the geometry of your real-time providers GNSS network without having to setup a base station.

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[1] Federal Communication Commission
[2] Radio Technical Commission for Maritime Services
[3] Parts per million

Cons of Subscription based services

As previously mentioned, the survey community has basically given up the ability to analyze or manipulate occupational data via Least Squares on baseline vectors, instead settling for a list of coordinates with propagated errors. In doing so, the surveyor is hampered in evaluating actual data quality of the NTRIP base corrections and should at a minimum check into known passive control monuments before and after the GPS survey to provide confidence in the GPS mission based on RTK Best practices. Should! Not to mention reoccupying a point to hopefully ensure the accuracy via the real-time precision.

Base and Rover RTK using Cellular Networks

Length Does Matter

Most GPS and Data Collection Manufacturers allow the storage of GPS Vectors for analysis and adjustment. RTK GPS Vectors are only available with Base Rover systems and thus are usually obtained using Spread Spectrum or UHF/VHF connections. Although most GPS and Data Collector manufactures allow for Rover connectivity for subscription based services, trying to make a base rover cellular connection is not supported by most manufacturers and where it is supported, it's definitely not plug and play. You would think this would have been the next step in standard RTK telemetry, but instead it has become the mystical unicorn of the industry.

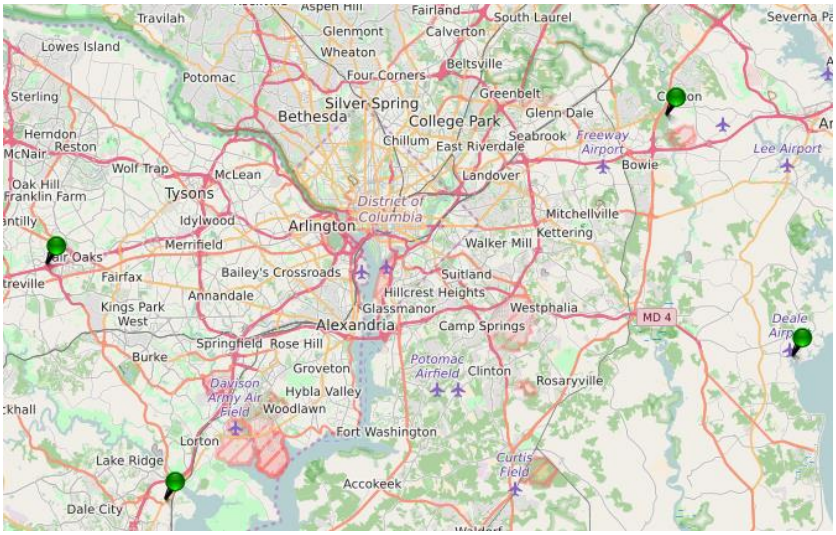
Leica GS14 and GS20

After doing pretty extensive research on base to rover connectivity, Thoth settled upon the Leica GS14 GNSS Base and Rover with internal support of both built in Verizon wireless as well as sim card based GSM Support. Working with John Phillips at Allen Precision, Thoth was able to create a base rover configuration using both Verizon CDMA[4] and AT&T GSM[5].

Network vs. Single Baseline Statistics

The GS14 data sheet details single baseline accuracies of Hz 8 mm + 1 ppm / V 15 mm + 1 ppm and Network RTK accuracies of Hz 8 mm + 0.5 ppm / V 15 mm + 0.5 ppm. Although the Network accuracies sound better at first blush, but if you are in Washington DC your nearest network station on one local provider would be 25 miles away. For 95% of our projects RTK baseline requirements are no more than 3 miles, but even at 10 miles you can do the math. If you are in more rural regions, you may not even be fortunate enough to have a subscription based solution.

[4] Code Division Multiple Access
[5] Global System for Mobile



Washington D.C. Network Coverage with KeyNetGPS

The ability to evaluate Vector Data

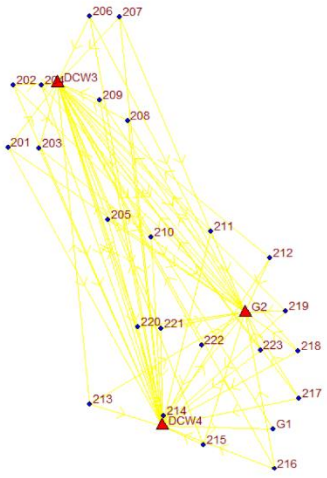
The ability to analyze and adjust survey data be it Static GPS, RTK, Conventional Trigonometric data or Differential Digital Leveling should be extremely important to any surveyor. Although there are a variety of Least Squares Evaluation and Adjustment Packages available, Thoth is a longtime user and proponent of StarNet, having been users since before the acquisition by MicroSurvey.

RTK from an Unknown Location

Because of the fact we are storing RTK Vectors for later analysis and adjustment, we can also process those vectors against an autonomously collected base position. By setting up the base and collecting Static data, we are able to post-process the base against multiple National Geodetic Survey (NGS) Continually Operating Reference Stations (CORS). Using the processed base position, we can then update and rectify the RTK Vector data using StarNet Least Square adjustment.

Redundant Vectors and Least Squares Analysis

Occupying a position multiple times either under differing satellite geometry and/or multiple control locations, we can evaluate real RMS[6] data that can be documented and provided in a report to the client or to defend oneself in court if necessary.



[6] Root Mean Square Statistical Analysis

Conclusion

If you go to any Society dinner or meeting, there will always be an argument about the accuracies of subscription based solutions. At the end of the day we have found that the horizontal accuracies are pretty solid, but we often see vertical errors of up to 0.2' between inter-visible pairs. Subscription providers also do not provide a guarantee of their corrections and recommend that the surveyor check known coordinates before and after every GPS survey. Vector data is not available because of the use of multiple stations or virtual stations so final analysis can only be based on NTRIP residuals or the average of multiple coordinate locations.

Using a Base Rover Solution cellular setup has provided Thoth with a solution that is at a much cheaper price point, provides long distance baseline RTK and allows us to control our observable data for analysis and adjustment. We believe as professionals, we have a responsibility to be able to justify and defend our data or else we are no better than the GIS professional with a survey grade budget. Moving forward, we would like to see the ability of a rover to handle multiple bases so that multiple vectors can be simultaneously collected removing or reducing the requirement of multiple occupations. In the end, it was a real pain to finally get the solution tweaked, but we couldn't be happier with the result.